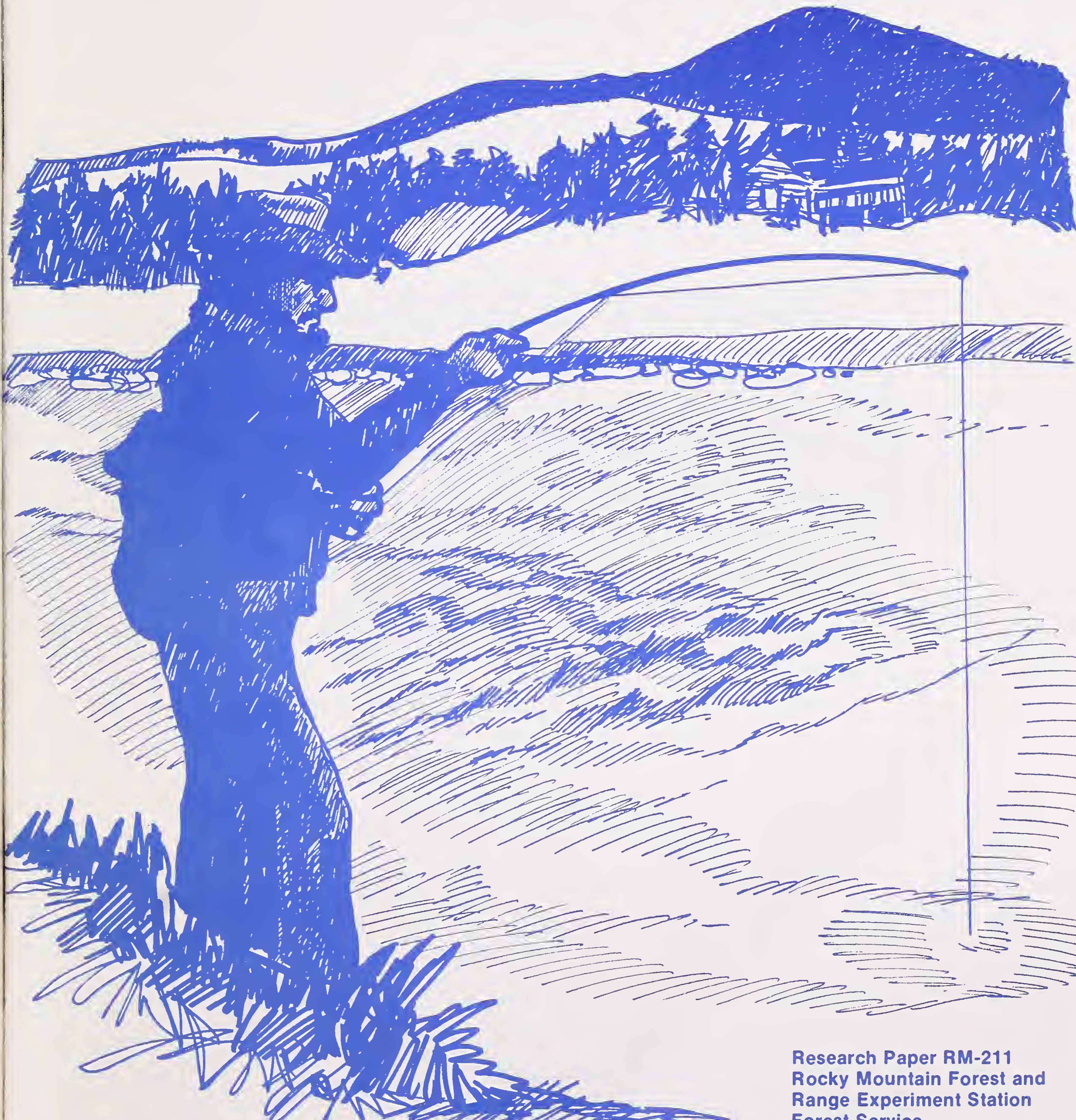
The Effect of Lake-based Recreation and Second Home Use on Surface Water Quality in the Manitou Experimental Forest

Stanley L. Ponce and Howard L. Gary



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Abstract

Measurements during one summer indicated dispersed fishing, picnicking, and use of sealed-vault outdoor toilets did not significantly degrade water in Manitou Lake. Poor siting of four long-established second homes on private lands along a stream increased total coliform, fecal coliform, suspended solids, and orthophosphate concentrations.

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MANAGEMENT IMPLICATIONS

Mountain homes and associated road systems adjacent to a live stream in the Manitou Experimental Forest had significant impacts on water quality. The White Spruce Gulch study area showed little impact, partially because of the lack of homes in the study area, but more so because of the proper road design and placement. The results at Hotel Gulch, on the other hand, demonstrate the poor design of roads and waste disposal systems in a second home development can have a distinct impact on stream water quality, particularly during and immediately after summer rainfall events.

Land managers should pay particular attention to design and construction of second home developments. Road systems should follow topographic contours and have properly sized culverts laid along the channel grade at stream crossings. Vegetative buffer strips of adequate width should also be maintained and/or established between the road and stream channel. In addition, water bars should be placed on the road surface to direct overland flow to buffer strips. Drainage water should be diverted out of ditches at intervals short enough to prevent ditch erosion. Sewage disposal systems should be designed in relation to stream proximity and the assimilative capacity of the soil.

Good planning for future roads, home sites and protection of vegetative cover on undeveloped private land within the Manitou Experimental Forest will directly reduce surface runoff and sedimentation in live streams. Better types and placement of home waste treatment systems will also help maintain the present aquatic habitat.

INTRODUCTION

As a result of recent water quality legislation, resource managers have become increasingly concerned with the impact of land management activities on the quality of the water resource along the Front Range urban corridor in Colorado. Mountain home developments, picnic areas, and campgrounds are commonly oriented around streams and lakes, and may cause degradation of water quality. The specific objective of this study was to quantify the impact of lake-based recreation and an old second home development on surface water quality in the Manitou Experimental Forest.

PAST WORK

Outdoor Recreation

Campground recreation and day-use recreation along streams and lakes do not always have a detectable impact on water quality. The magnitude of the impact appears to be a function of the type of activities and intensity of uses.

Brickler and Utter (1975) found the most prominent source of water contamination in developed recreation areas in Arizona was sewage disposal facilities. Due to heavy use and overloading, such facilities may become sources of biological and nutrient contamination. This is

important because the biological contamination can be a direct health risk to downstream users while the nutrient input may lead to eutrophication in adjacent mountain lakes or in downstream reservoirs.

Johnson and Middlebrooks (1975) reported picnicking and campground use resulted in degradation of stream quality in Utah's Wasatch Front. They found sharp increases of fecal coliform counts coincided with peak recreational use while concentration and mass flow of fecal coliforms dropped sharply at the end of the recreation season. This indicates a direct relationship between stream quality and user intensity.

Aukerman and Springer (1976), studying the Little South Fork of the Cache la Poudre River in the Central Rockies, found small increases in fecal coliform counts at areas accessible by paved roads. However, areas reached only by unpaved roads and footpaths showed no increase. Schillinger and Gordon (1976) reported similar results on the Hyalite drainage near Bozeman, Mont.

Brickler and Utter (1975) also presented general management guidelines to limit further deterioration of water quality in recreational lakes and streams in Arizona. They reported specific recreational areas and activities have individual problems, such as turbidity, nitrates, orthophosphates, and minor fecal contamination. These problems usually require management actions not universally applicable.

Recreation Home Development

Homes used for recreation or as primary residences are increasing rapidly on private lands in and near national forests. Construction, disposal of sewage, and increased recreation associated with home development may generate many types of water contaminants.

Sediment is the most prevalent water pollutant associated with recreational home development (U.S. Environmental Protection Agency 1973). Sediment comes from roads associated with development; road cuts and fills, stream crossings, road surfaces, and site clearing and grading for home construction are all potential sources of sediment (Howe 1972).

Sewage disposal systems including septic tank and leach fields are the primary source of biological contamination of waters draining mountain home developments (Howe 1972). Brickler and Utter (1975) reported bacterial contamination (fecal coliform) in groundwater resulting from a poorly designed leach field associated with a recreation area. Exceedingly high concentrations of coliform organisms have also been reported for mountain home developments in Colorado (Millon 1970, Burns et al. 1973). Wadleigh (1968) found that sewage effluent in a secluded valley of California was the main source of high nitrate concentration in groundwater.

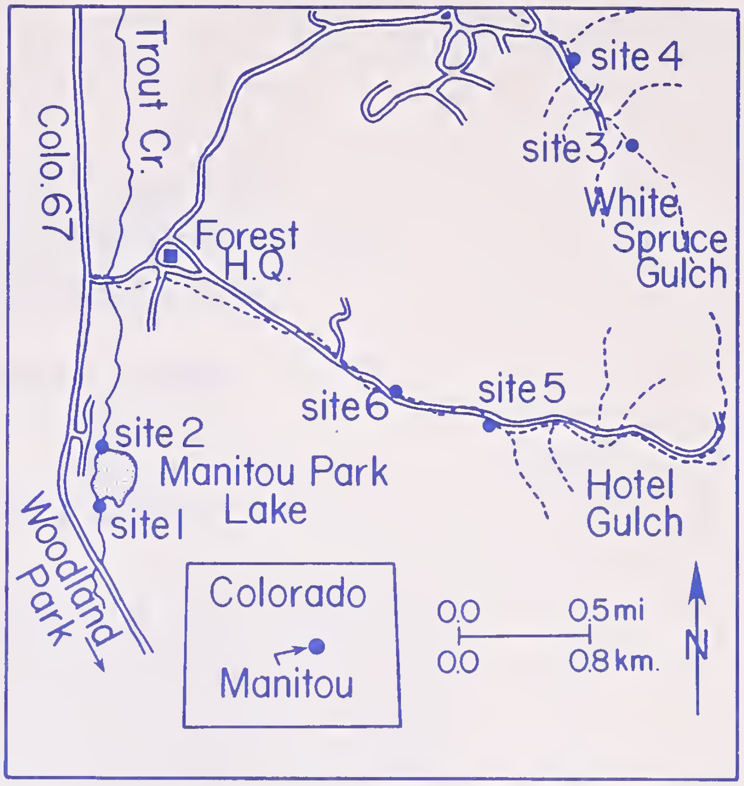

Figure 1.—Location of study sites within the Manitou Experimental Forest.

The utility of soil for sewage treatment is dependent on many factors—including physical characteristics, such as soil texture, depth, slope, percolation rate, moisture content, and chemical and biological factors, such as pH and the presence of soil microbes (Orlob and Krone 1966, Romero 1970). However, when soil conditions are not limiting, septic tanks and leach field systems are an effective means of sewage treatment (Segall 1976).

STUDY AREA

Local Characteristics

The study area is about 45 km northwest of Colorado Springs, Colo., in the Manitou Experimental Forest on a section of Trout Creek, a major headwaters tributary of the South Fork of the South Platte River (fig. 1). This area is representative of much of the Front Range of the Colorado Rockies.

The vegetation consists principally of dense to open stands of ponderosa pine and native bunchgrasses on the drier sites and Douglas-fir on moist north aspects. Topographic features include ridges, narrow mountain valleys, and large broad parks. The valley and park soils have developed from alluvial material derived from Pikes Peak

granite. These gravelly soils are highly permeable, unstable, and erode when protective plant cover is removed.

The climate is characterized by dry and cold winters and cool summers. Annual precipitation, largely rain, averages about 430 mm with about three-fourths of the total falling between April 1 and September 30. Streamflow in the study section of Trout Creek usually ranges from about 0.5 m^3/sec at the height of the spring runoff in May to less than 0.01 m^3/sec in October.[2]

The general study area was settled more than 100 years ago. Most of the easily accessible timber was logged before 1900, and the area was heavily grazed by cattle and horses until the early 1930's. In the late 1930's most of the land was transferred to the USDA Forest Service. The remaining area in private ownership has been used primarily for livestock grazing, but it is anticipated that much of this land will be developed for residential communities in the future.

Study Site Description

Manitou Lake

The effect of lake-based recreation was examined at Manitou Lake. This shallow manmade lake has about 5 ha of surface and has an earth fill dam with a concrete spillway (fig. 2). The steep slope of the dam face is well protected by rock riprap. Elevation is 2,358 m. Parking areas for vehicles are more than 60 m from the lake. There are three sets of outdoor toilets above the dam along the west bank about 75 m from the water's edge. All waste is contained in sealed vaults. The developed west shore is a heavily used picnic area, with all tables more than 25 m from the lake. Fishing is the major recreational activity. Swimming is prohibited but occurs on occasion. Recreationists have full access to the lake perimeter. Daily visitor use starting in May ranges from none during stormy weather to several hundred during peak use. Visitor use is heaviest on weekends and remains heavy until freezup in late fall.

[2]*Unpublished data on file. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 80526.*

Figure 2.—Manitou Lake recreational area.

Two sites were established to monitor the effect of recreation on the quality of the lake water. Site 1 was located immediately above the lake on Trout Creek, and site 2 was at the outlet on the spillway (fig. 2).

Home Development

The collective effect of four second homes established 20 to 30 years ago on surface water quality was examined on an intermittent tributary to Trout Creek. Study sites were established immediately above and below a 0.6-km reach of privately owned land in Hotel Gulch (fig. 1). Site 5, above the housing, was at 2,532 m elevation; and site 6, below the housing, was at 2,462 m. The homes were in a narrow east-west oriented canyon with steep, well shaded side slopes. Tree cover is mainly old-growth Douglas-fir and aspen. The stream was perennial throughout the study, but flows are generally intermittent during July and August.

The only access through the area is an old unimproved bulldozed road 3 to 3.5 m wide. The road ranges from about 0 to 3 m above the stream and is generally less than 5 m from the stream. The road crosses the stream twice (over culverts) about halfway through the study reach. Three homes were on the south side of the creek and one on the north side. All homes were less than 15 m from the stream. Two of the homes had septic tanks and leach fields. The septic tank and leach field for one home were less than 8 m from the stream and less than 1 m above the usual stream level. Two homes had outdoor toilets. The pits, less than 15 m from the stream, were not lined or sealed and were in a rundown condition. Each of the rustic second homes were continuously occupied by two or more people during the period of study (fig. 3).

As one check on effects of home development, a section of unimpacted stream on White Spruce Gulch (private land platted for large-lot development) was also sampled to ascertain changes that may occur without development (fig. 1). Vegetation in the canyon and near the stream was similar to that in Hotel Gulch. Elevation at site 3 was 2,520 m and at the lower (site 4) 2,455 m. The horizontal distance between sites was also 0.6 km. The only development within this canyon was a 3- to 4-m-wide, good quality, gravel access road generally 10 to 15 m from the stream and one spur road to gain access to westerly facing lots located above the

stream channel (fig. 4). Gravel roads like the one mentioned above may erode during intense rainstorms. The road crossed the stream three times over culverts near the center of the study reach, and once directly through the stream.

METHODS

Field Measurements

A record of daily precipitation was obtained from a recording gage at the headquarters of the Manitou Experimental Forest. Instantaneous discharge (Q) was determined using area-velocity when flow volume permitted. A pygmy-type current meter was used to measure water velocity; however, when flows on Hotel and White Spruce Gulches were very low, discharge was measured in control sections below rock-constructed waterfalls using a liter-graduated cylinder and stopwatch. Water temperature (TEMP) was measured using a laboratory-grade mercury thermometer.

Grab samples of lake or stream water were collected in sterile polyethylene bottles. The stream samples were taken in midstream and integrated over the entire depth when flow permitted. During the very low flows on Hotel and White Spruce Gulches, samples were taken from the artificial waterfalls described earlier. Water samples were immediately placed in an ice chest and refrigerated after transporting to the laboratory at the Manitou Experimental Forest headquarters. All analyses were preformed as soon as possible after collection, usually within 24 hours.

Sampling Frequency

A scheme for routine sample collection was developed to monitor two distinct periods of use: weekdays and weekends. Samples were collected every Thursday and Sunday from June 17 through October 3, 1976, at each of the six sites in order to test user intensity. At the beginning of the study, a diurnal test over a 24-hour period indicated very little change in the water quality, and it was concluded composite sampling was not necessary. As a result, single grab samples were taken at nearly the same time at each site during the routine collection. The samples were analyzed for suspended solids (SS), TEMP, orthophosphate (PO_4), total coliform (TC), and fecal coliform (FC).

Figure 3.—Rustic second home in Hotel Gulch.

Figure 4.—Graded road with berms and ditches protect the stream channel in White Spruce Gulch.

The most intensive use of Manitou Lake occurred during the July 4 holiday. This holiday period was monitored utilizing a week-long study from July 1 through 7, 1976. Grab samples were taken twice daily, in the morning at 9 a.m. and in the evening at 8 p.m. The samples were analyzed for SS, TC, and FC.

It was suspected runoff resulting from summer rainstorms would act as a major mechanism transporting pollution to the streams. Two events were sampled on Hotel Gulch only. Samples were collected as frequently as possible during the entire storm hydrograph and analyzed for SS, TC, and FC.

Laboratory Measurements

SS concentrations were determined using the nonfilterable residue procedure outlined by the American Public Health Association, Inc. (1975). High concentration of SS in stream water may kill fish and other aquatic life by causing abrasion injuries, and clogged gills and respiratory passages. Indirectly, SS may also carry and trap bacteria and decomposing organic wastes on stream bottoms which may result in oxygen depletion.

PO_4 concentration, the only phosphate form determined directly, was measured by the ascorbic acid method (American Public Health Association, Inc. 1975). Surface waters containing more than 200 $\mu g/l$ of phosphates generally indicate pollution

from agricultural fertilizer runoff, water treatment plants, or leaching from septic tanks (McKee and Wolf 1963).

The presence of TC and FC was determined by the membrane filter technique (American Public Health Association, Inc. 1975). These bacteria, always present in intestinal tracts of warm-blooded animals, are eliminated in large numbers in fecal waste. They are not usually pathogenic themselves and do not generally multiply outside the intestines, but are often found in the company of intestinal pathogens affecting man and other mammals. Their presence usually indicates that intestinal waste products have reached a water source.

Water samples for bacteriological analyses were collected in sterile bottles, filtered, and prepared within 6 hours of colletion. Three levels of sample concentration were examined for each sample, 100, 10, and 1 ml.

Statistical Analyses

Two basic statistical analyses were performed. First, a measure of central tendency was made with the data collected routinely on Thursday and Sundays. The mean was calculated for SS, TEMP, and PO_4, while the median and range of counts per 100 ml were determined for TC and FC. Second, the data were tested for significance by the "t" test for paired differences. Significance referred to throughout this paper was the 5% level of probability ($p = 0.05$). Paired differences were computed for Thursday versus Sunday at each sampling site, morning versus evening during the week-long study at Manitou Lake, and upstream versus downstream at each study section over the entire study period (only Thursday and Sunday data used in this analysis), the Manitou Lake week-long study, and the storm runoff on Hotel Gulch.

RESULTS AND DISCUSSION

Manitou Lake

Although recreation user intensity varied, water quality remained virtually unchanged from Thursday to Sunday in any given week. Counts of people using the area revealed an average of 84 on Thursdays and 225 on Sundays (fig. 5). No significant difference was found for any of the parameters sampled when Thursdays (low visitor days) were compared with Sundays (high visitor days). These results suggest user intensity (within the limits examined) had little effect on water quality in Manitou Lake. These results were in contrast to those noted earlier for Utah's more heavily used Wasatch Front (Johnson and Middlebrooks 1975).

A summary of results of routine sampling for the inlet and outlet sample points is given in table 1, and figure 6 illustrates time trends of selected parameters. SS concentration for the two sites averaged about 25 mg/l. SS concentrations were highly variable in June and July, but there was no apparent correlation between discharge and SS concentration at either site (fig. 6). For the local area,

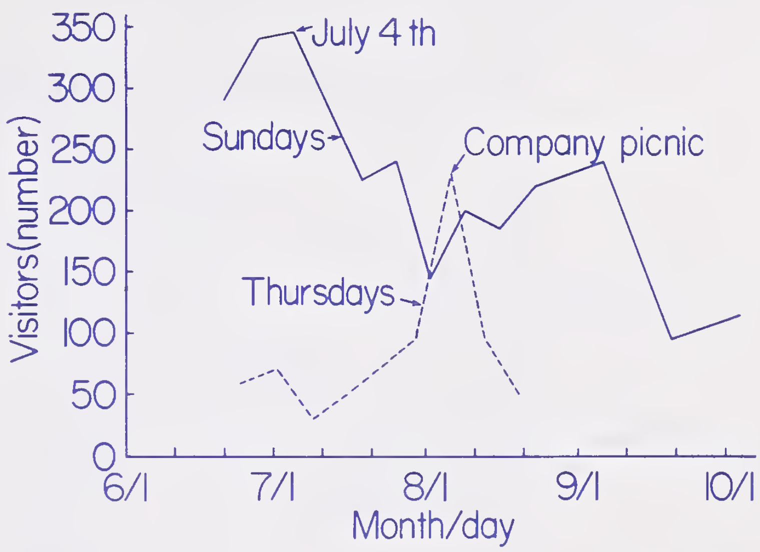

Figure 5.—Number of visitors at noon for selected Thursdays and Sundays at Manitou Lake, summer of 1976.

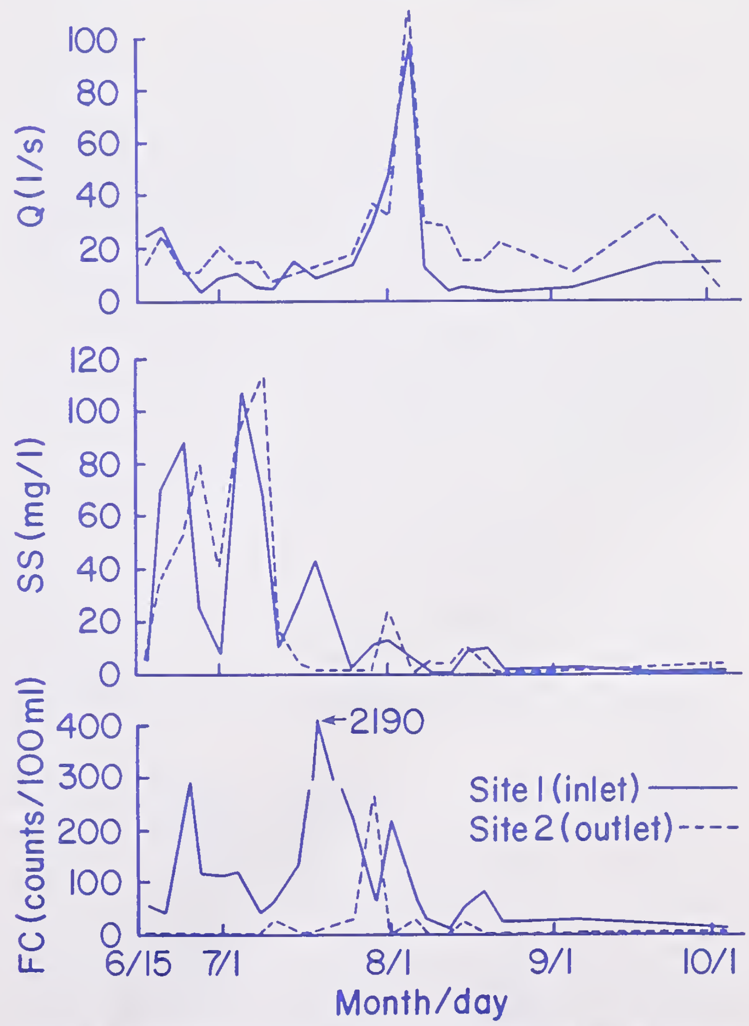

Figure 6.—Streamflow (Q), suspended solids (SS), and fecal coliform (FC) at Manitou Lake.

Table 1. Summary of routine sampling at Manitou Lake from June 17 to October 3, 1976

Site (location)	SS	TEMP	PO_4		TC	FC
	mg/l	*°C*	*µg/l*		*Counts per 100 ml*	
1 (Inlet)	Mean 24.8	17	87	Median	66	64
				range	0-2050	11-2179
2 (Outlet)	Mean 24.5	17	42	Median	13	1
				range	0-250	0-270

Table 2. Summary of daily counts of total and fecal coliform (TC and FC) bacteria at Manitou Lake from July 1 to 7, 1976

Date	Site	Morning sample TC	FC	Visitors	Evening sample TC	FC
		Counts per 100 ml		*Number at 3 p.m.*	*Counts per 100 ml*	
July 1	1	270	103	69	180	92
	2	42	1		28	1
July 2	1	75	29	30	280	220
	2	20	1		3	1
July 3	1	106	98	136	72	162
	2	4	0		23	2
July 4	1	92	120	345	24	44
	2	1	0		0	0
July 5	1	230	92	225	83	40
	2	9	0		56	7
July 6	1	258	192	29	461	88
	2	9	5		15	4
July 7	1	132	20	22	136	48
	2	14	1		39	0

annual acumulations of SS, composed mainly of organic and mineral material, are characteristically flushed out during the spring and early summer. Recreational activities at Manitou Lake apparently had no practical effect on SS concentrations.

Recreation activities around the lake and use of sealed-vault outdoor toilets also had little impact on the microbe levels in the lake. Median concentrations of FC dropped from 64 counts per 100 ml at the inlet to 1 count per 100 ml at the outlet. In the week-long study for July 1 to 7, 1976, TC and FC counts at the inlet were all significantly higher than TC and FC counts at the outlet (table 2). Effluent concentrations of FC at the outlet were continually near zero irrespective of user intensity or time of day. Visitor use above the lake ranged from about 350 people at noon on July 4 to less than 25 on July 7.

The nutrient and temperature conditions of the lake were conducive to aquatic plant growth. Average TEMP and PO_4 concentration were 17° C and 64 µg/l, respectively. Although water temperature and nutrient concentration may have caused development of algal growths observed in shallower portions of the lake, the data do not suggest the recreational use of the lake affects these two constituents appreciably. There is little difference in the average TEMP at the inlet and at the outlet (table 1), apparently because water entering the lake has been heated to its capacity. In addition, average PO_4 concentration in the effluent is less than half that in the influent. The PO_4 causing algal growth was probably derived outside the study reach and not the result of recreation use at the lake.

Mountain Home Development

White Spruce Gulch

None of the parameters monitored on this undeveloped area were significantly different in the upstream and downstream sites (table 3). Concentrations of SS were relatively low and averaged about 22 and 24 mg/l at the upstream and downstream sites, respectively. SS concentrations were highest in June in response to higher streamflow (fig. 7). High intensity summer rainstorms increased streamflow during August but did not increase SS and apparently indicated a threshold value of discharge had to be surpassed before SS were transported. The low SS concentrations during the summer also indicated few if any sediments came from the access road in White Spruce Gulch.

Hotel Gulch

Results of a paired comparison test indicated a significant difference between the upstream and downstream counts of TC and FC (table 3).

Similarly, the average concentration of SS was about 16 mg/l at the upstream site and about 22 mg/l at the downstream site (table 3). From mid-June to early July, SS were relatively high and similar trends were exhibited at both sites (fig. 8). Concentrations of SS at both sites dropped to relatively low values before the start of summer rains. After the rains began, increased sediment loading in the stream below the housing area was readily apparent, while streamflow volumes were about the same at each site.

TEMP averaged nearly 2° C higher in the downstream direction in Hotel Gulch (fig. 8), apparently in response to variable shading over the stream.

Mean PO_4 concentrations for the routine sampling were 33 µg/l at the upstream site and 43 µg/l at the downstream site (table 3, fig. 9). These concentrations were similar to those reported draining through granites by Hem (1970).

In general, the PO_4 concentration tended to respond inversely to discharge, indicating a fairly constant mass of PO_4 was delivered to the stream and probably derived from natural sources, such as rocks and soil, rather than from sewage (fig. 9). However, slightly higher levels of PO_4 downstream do not preclude a partial input from sewage.

FC concentrations were significantly higher downstream from the development (fig. 10). The median concentration was 20 counts per 100 ml at the upper site and 40 counts per 100 ml at the downstream site. This trend was different than observed for the White Spruce Gulch stream section where there is no home development. This apparently indicates contamination of stream water in Hotel Gulch, perhaps from sewage disposal. This observation was further supported by a high temporal relationship between storm runoff in midsummer and FC concentration.

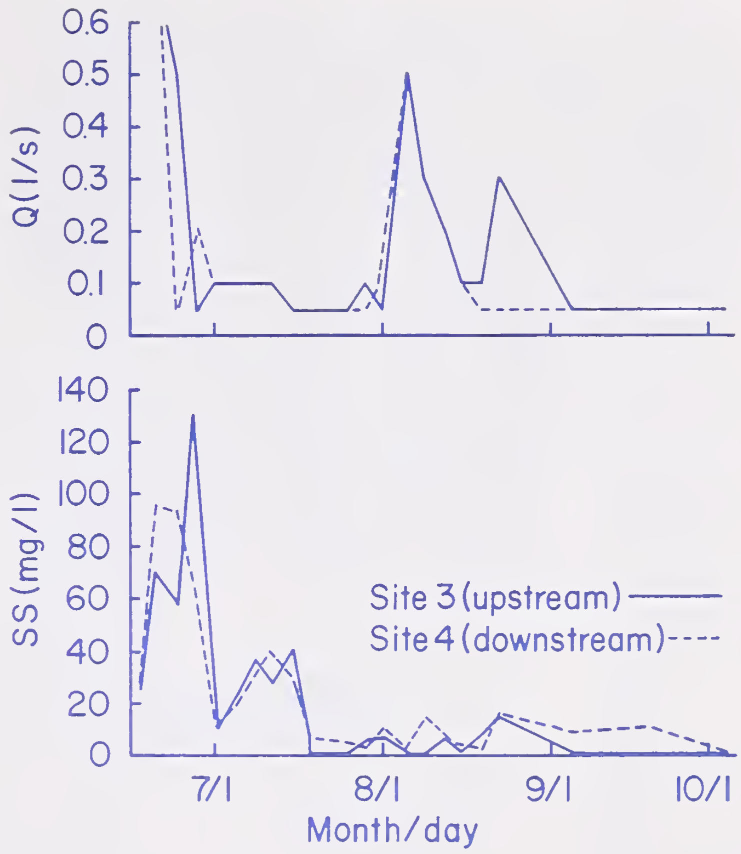

Figure 7.—Streamflow (Q) and suspended solids (SS) along an undeveloped stream section in White Spruce Gulch.

During the study, runoff from two storms was monitored at Hotel Gulch. Paired comparison tests for each storm showed significant differences in SS, TC, and FC at the upstream and downstream sites. Results of the July 18 storm are illustrated in figure 11. This storm produced 10 mm of rain in a 1- hour period. Streamflow increased substantially through the study reach. The contrast between the sharp peak observed at the downstream site and the gradual rise in discharge upstream indicates surface runoff directly into the stream.

Table 3. Summary of routine sampling for White Spruce and Hotel Gulches, June 17 through October 3, 1976

Site (location)	SS	TEMP	PO_4		TC	FC
	mg/l	*°C*	*µg/l*		*Counts per 100 ml*	
	White Spruce Gulch (undeveloped)					
3 (upstream)	Mean 21.9	6.3	32	Median	7	0
				range	0-260	8
4 (downstream)	Mean 23.5	8.0	40	Median	6	0
				range	0-68	0-72
	Hotel Gulch (developed)					
5 (upstream)	Mean 15.5	8.1	33	Median	20	0
				range	0-134	0-3
6 (downstream)	Mean 22.3	10.0	43	Median	40	3
				range	0-114	0-92

SS concentration increased with discharge in the downstream direction. SS at the upper sampling site did not exceed 102 mg/l and, in general, remained below 20 mg/l. At the downstream site, SS peaked at 2,500 mg/l. It was apparent from field observations that sediment was derived primarily from the road adjacent to the stream, and to a lesser extent, from the home sites. The stream channel apparently contributed a minor amount of sediment, as evidenced by the response of the upstream site.

A substantial increase also occurred in FC concentration at the downstream site during the storm. The concentration upstream remained near zero, while it exceeded 7,000 counts per 100 ml downstream. The high surge in FC was probably caused by flushing a detention storage carrying surface-derived FC, perhaps from the outdoor toilets.

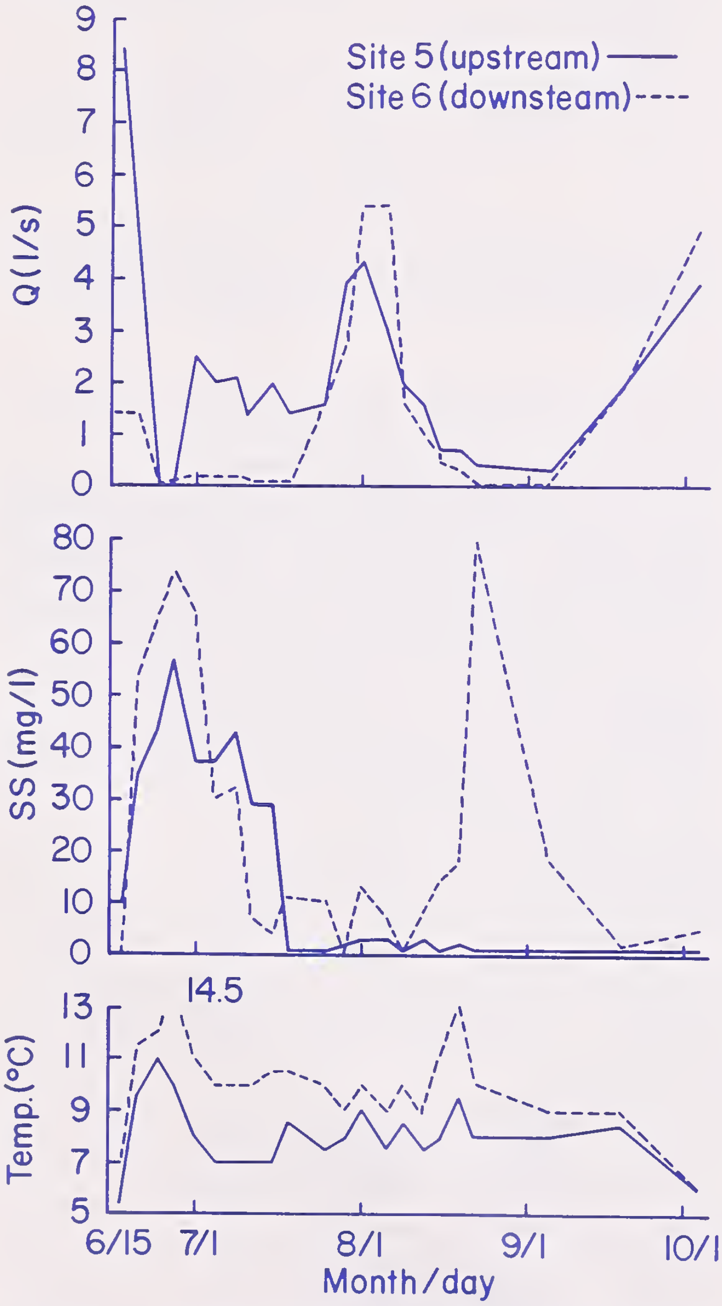

Figure 8.—Streamflow (Q), suspended solids (SS), and temperature (TEMP) along a developed stream section in Hotel Gulch.

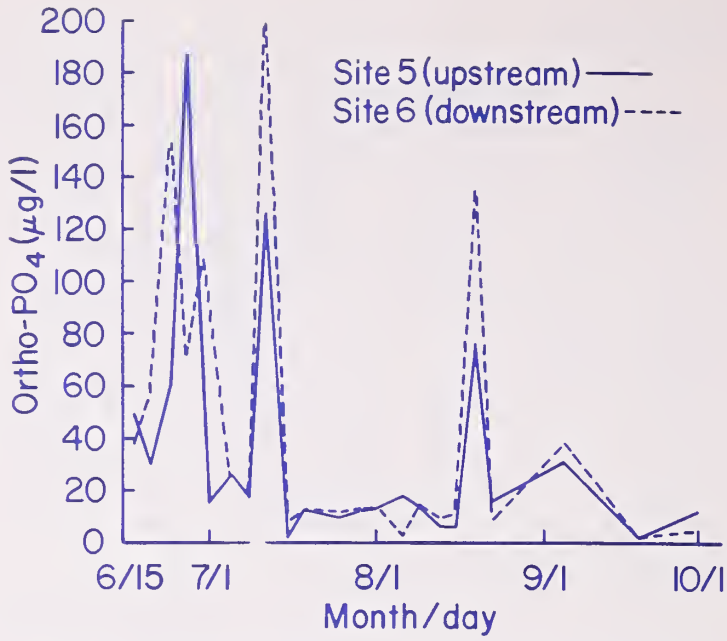

Figure 9.—Orthophosphate (PO_4) trends in Hotel Gulch.

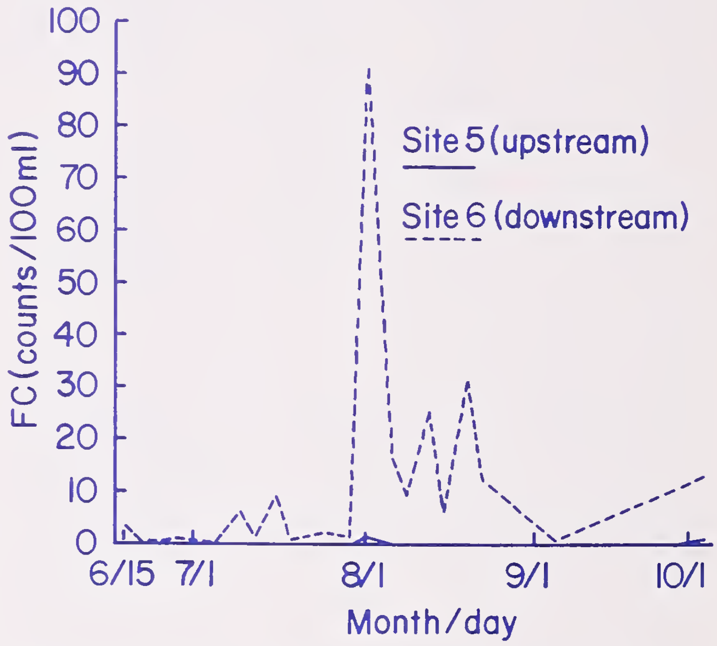

Figure 10.—Fecal coliform (FC) trends in Hotel Gulch.

Results of the July 21 storm are illustrated in figure 12. This small storm produced 5.1 mm of rain in less than 1 hour. Significant increases in the downstream direction were again observed for SS and FC. Peak runoff was nearly equal to that of the July 18 storm flow, while SS and FC concentrations were much lower. The reduction in SS and FC concentrations was apparently the result of the "flushing" action of the storm runoff occurring 3 days earlier. However, it should be noted that even though the pollutant concentration was lower, the home development was the apparent major source of the stream water contamination.

CONCLUSIONS

Recreational use at Manitou Lake did not significantly degrade water quality for the one season of study, based on the water constituents examined. In fact, water quality improved as the water passed through the lake. FC and SS concentrations were all reduced substantially, while the other constituents sampled remained relatively unchanged.

Several differences in water quality directly related to land use were noted between developed and undeveloped study areas on Hotel Gulch and White Spruce Gulch. SS concentration was slightly greater at the developed area. This was apparently caused by increased sedimentation from road cut material cast near the stream channel and close siting of homes near the stream channel.

TC and FC densities were the most sensitive indicators to characterize land use differences. These bacteriological parameters increased significantly as water moved through the inhabited Hotel Gulch study area, while little change was noted in the undeveloped White Spruce Gulch study area.

Home development had the greatest impact on stream water quality during and immediately following rains. The hydrograph at the downstream site in Hotel Gulch illustrated a much more rapid response to precipitation than the upstream station. SS rose from near zero to several thousand mg/l while similar results were observed for FC. The majority of runoff and sediment was derived from the road and surface flow from bare and disturbed areas around the home sites. Increased FC probably resulted from increased surface runoff around the homes and, perhaps, contamination by sewage.

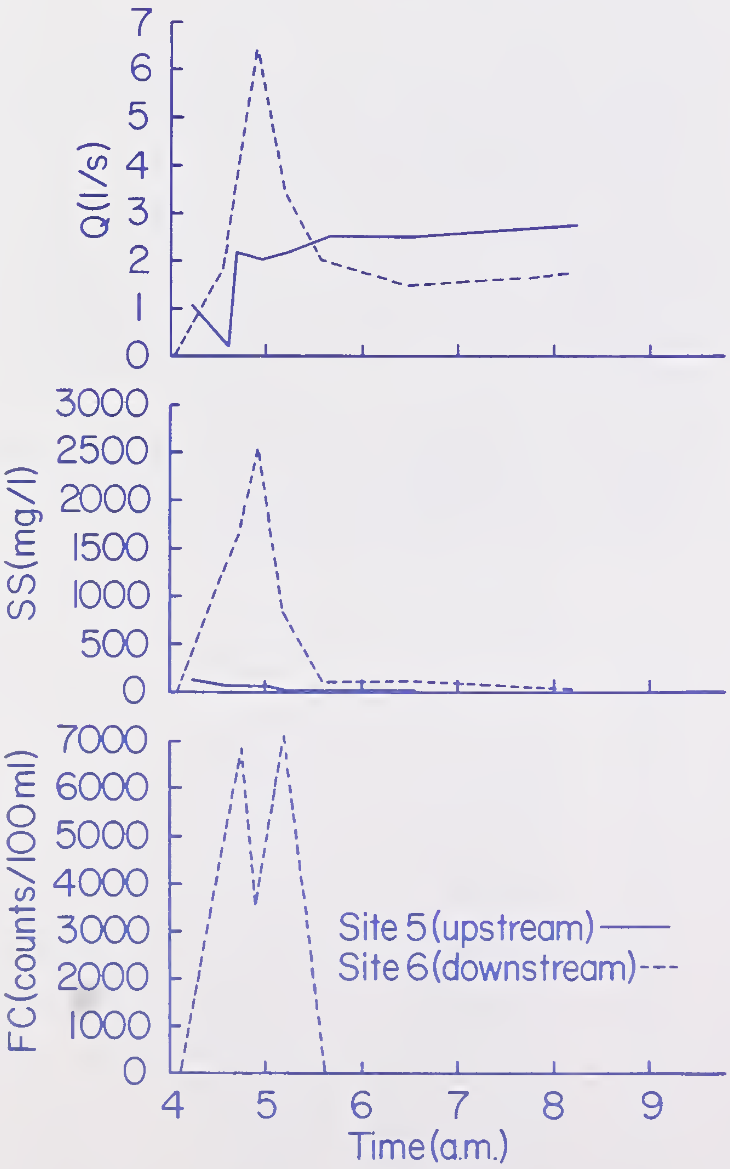

Figure 11.—Streamflow (Q), suspended solids (SS), and fecal coliform (FC) on July 18, 1976, in Hotel Gulch.

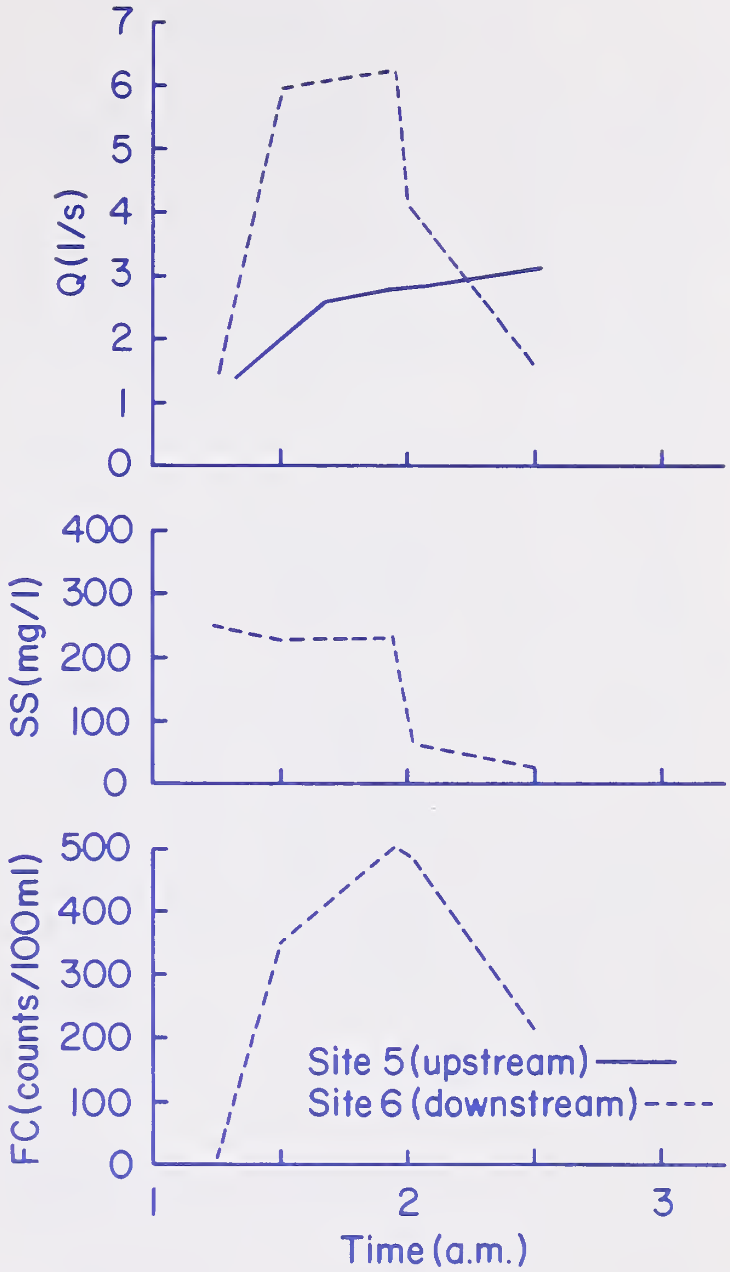

Figure 12.—Streamflow (Q), suspended solids (SS), an fecal coliform (FC) on July 21, 1976, in Hotel Gulch.

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Keywords: Water quality, recreation, mountain homes, montane

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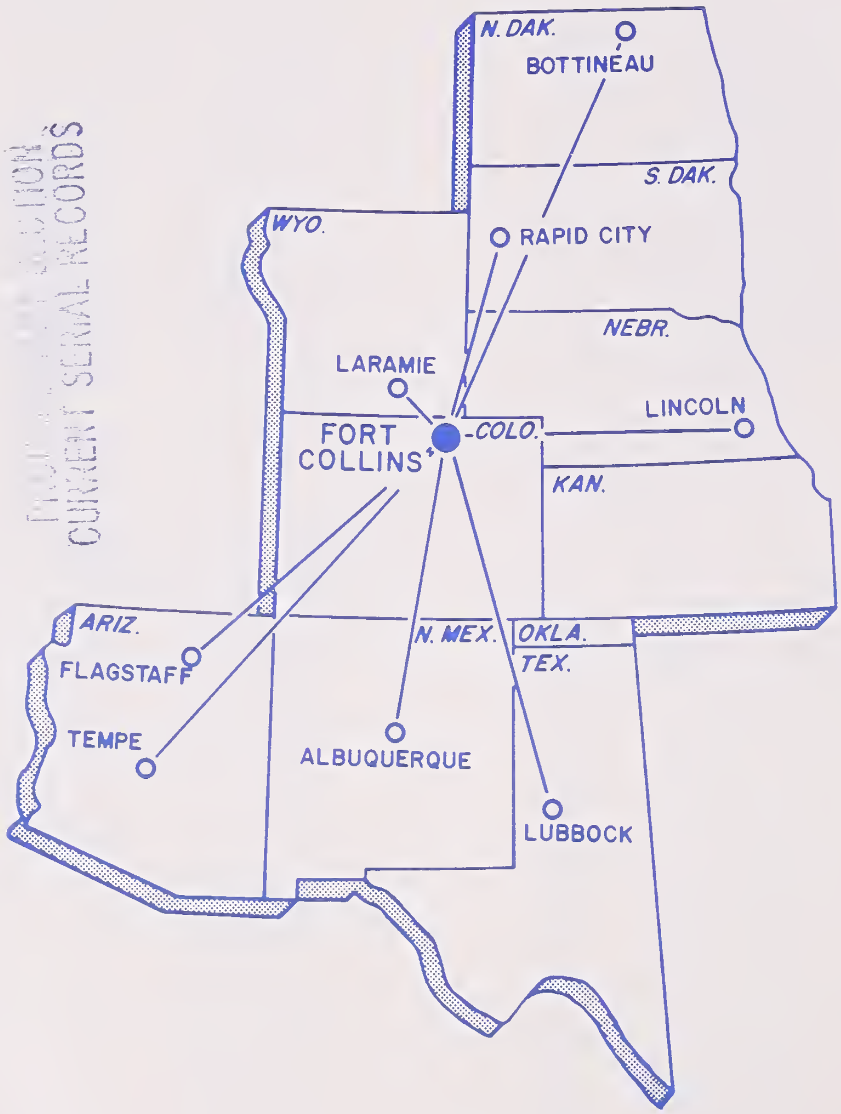
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